# Summary

Two endemic fishes of the upper Klamath basin (Figure S-1), the shortnose sucker (*Chasmistes brevirostris*) and the Lost River sucker (*Deltistes luxatus*), were listed as endangered under the federal Endangered Species Act (ESA) in 1988 by the U.S. Fish and Wildlife Service (USFWS). USFWS cited overfishing, water management, habitat alteration, nonnative species, poor water quality, and several other factors as likely contributors to the decline of the fishes, which once were very abundant. In 1997, the Southern Oregon Northern California Coast "evolutionarily significant unit" of coho salmon (*Oncorhynchus kisutch*), which is native to the Klamath basin and several adjacent drainages, was listed by the National Marine Fisheries Service (NMFS) as threatened under the ESA. NMFS cited water management, water quality, loss of habitat, overfishing, and several other potential causes of decline for the coho salmon.

In 2001, in response to biological assessments prepared by the U.S. Bureau of Reclamation (USBR), the two listing agencies issued biological opinions that required USBR to take numerous actions, including maintenance of higher water levels in Upper Klamath Lake and two reservoirs on the Lost River and higher flow of the Klamath River below Iron Gate Dam. Release of the two biological opinions coincided with a severe drought. Because of the new biological opinions and the drought, USBR was prohibited from releasing large amounts of water to farmers served by its Klamath Project, which diverts waters from Upper Klamath Lake and the upper Lost River for use in irrigation through USBR's Klamath Project. The unexpected restrictions on water supply, which severely impaired or eliminated agricultural production on the 220,000 acres irrigated by the Klamath Project, caused agricultural water users and others to question the basis for water restrictions, while other parties, fearing adverse effects of the Klamath Project on the endangered and threatened fishes, supported the restrictions.

In late 2001, the Department of the Interior and the Department of Commerce asked the National Academies to form a committee (the Committee on Endangered and Threatened Fishes in the Klamath River Basin) to evaluate the strength of scientific support for the biological assessments and biological opinions on the three listed species, and to identify requirements for recovery of the species. The committee was charged to complete an interim report in early 2002, focusing on effects of the Klamath Project, and to complete a final report in 2003 that would take a broad view of the scientific aspects of the continued survival of the listed species (Box S-1). This is the committee's final report.

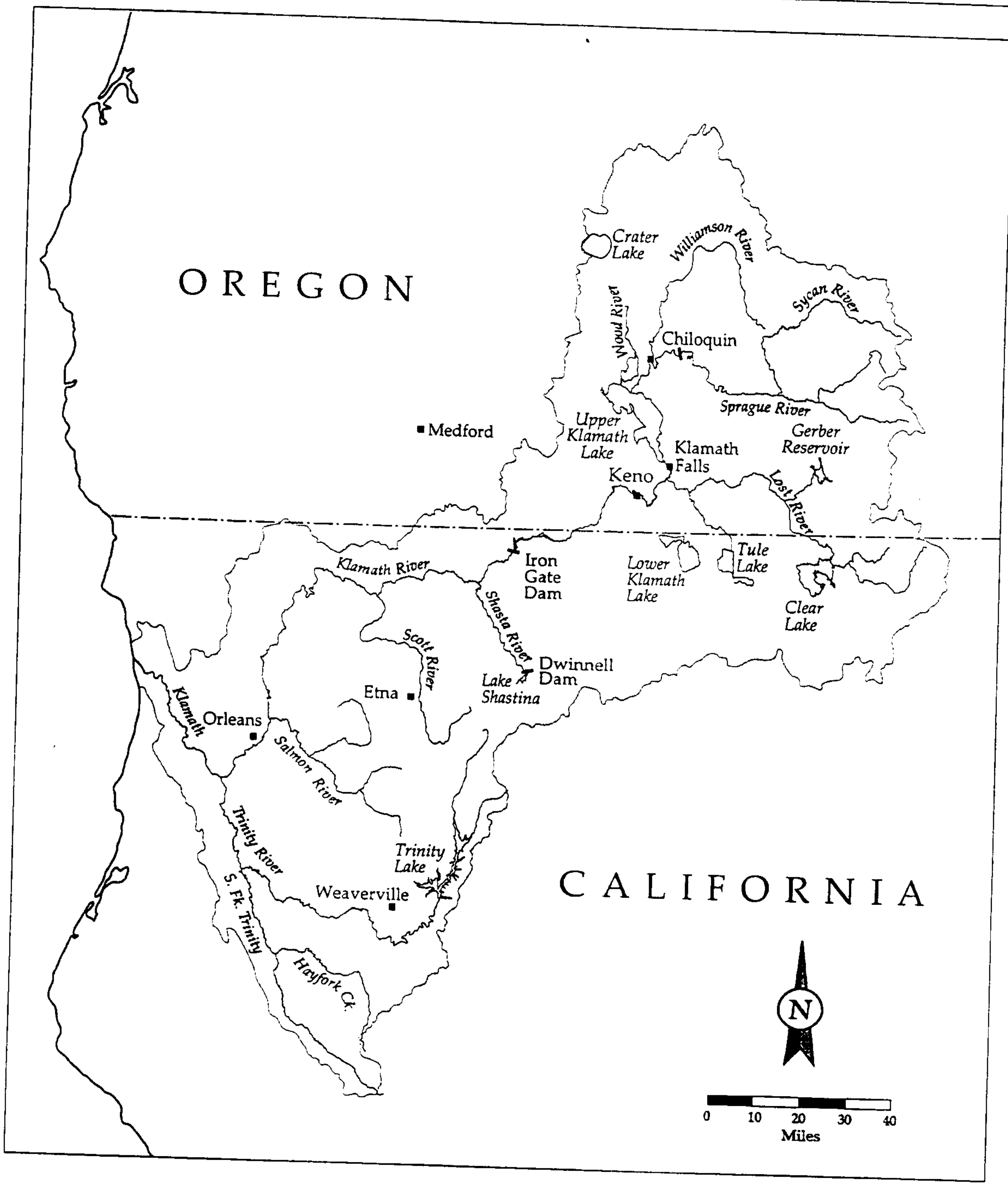


Figure S-1. Map of the Klamath River basin showing surface waters and landmarks. Source: modified from USFWS.

In its interim report of February 2002, the committee found substantial scientific support for all recommendations made by the two listing agencies for the benefit of the endangered and

Box S-1. Statement of Task

The committee will review the government's biological opinions regarding the effects of Klamath Project operations on species in the Klamath River Basin listed under the Endangered Species Act, including coho salmon and shortnose and Lost River suckers. The committee will assess whether the biological opinions are consistent with the available scientific information. It will consider hydrologic and other environmental parameters (including water quality and habitat availability) affecting those species at critical times in their life cycles, the probable consequences to them of not realizing those environmental parameters, and the inter-relationship of these environmental conditions necessary to recover and sustain the listed species.

To complete its charge, the committee will:

1. Review and evaluate the science underlying the Biological Assessments (USBR 2001a,b) and Biological Opinions (USFWS 2001; NMFS 2001).

2. Review and evaluate environmental parameters critical to the survival and recovery of listed species.

3. Identify scientific information relevant to evaluating the effects of project operations that has become available since USFWS and NMFS prepared the biological opinions.

4. Identify gaps in the knowledge and scientific information that are needed to develop comprehensive strategies for recovering listed species and provide an estimate of the time and funding it would require.

A brief interim report will be provided by January 31, 2002. The interim report will focus on the February 2001 biological assessments of the Bureau of Reclamation and the April 2001 biological opinions of the U.S. Fish and Wildlife Service and National Marine Fisheries Service regarding the effects of operations of the Bureau of Reclamation's Klamath Project on listed species. The committee will provide a preliminary assessment of the scientific information used by the Bureau of Reclamation, the Fish and Wildlife Service, and the National Marine Fisheries Service, as cited in those documents, and will consider to what degree the analysis of effects in the biological opinions of the Fish and Wildlife Service and National Marine Fisheries Service is consistent with that scientific information. The committee will identify any relevant scientific information it is aware of that has become available since the Fish and Wildlife Service and National Marine Fisheries Service prepared the biological opinions. The committee will also consider any other relevant scientific information of which it is aware.

The final report will thoroughly address the scientific aspects related to the continued survival of coho salmon and shortnose and Lost River suckers in the Klamath River Basin. The committee will identify gaps in the knowledge and scientific information that are needed and provide approximate estimates of the time and funding needed to fill those gaps, if such estimates are possible. The committee will also provide an assessment of scientific considerations relevant to strategies for promoting the recovery of listed species in the Klamath Basin.

threatened species, except for recommendations requiring more stringent controls over water levels in Upper Klamath Lake and flows at Iron Gate Dam. The committee also noted, however, that USBR had not provided any substantial scientific support for its own proposal of revised operating procedures, which might have led to lower mean water levels or lower minimum flows.

In 2002, USBR issued a new biological assessment that dealt with the two endangered sucker species and the threatened coho salmon. In response, USFWS prepared another biological opinion on the suckers, and NMFS prepared another biological opinion on the coho salmon. These documents reflect a closer interaction between the agencies than in previous years. USBR moved toward more restrictive operational practices than it had previously proposed and toward development of reserve water supplies; USFWS and NMFS were more cautious in requiring actions whose basis would be contradicted by site-specific studies, and they acknowledged the need to consult with parties in addition to USBR. The biological assessment and the two biological opinions for 2002 cover a 10-yr interval (2002-2012), during which time the listing agencies may require additional consultation and may revise their biological opinions.

## PRINCIPAL FINDINGS OF THE COMMITTEE

### Lost River and Shortnose Suckers

#### Upper Klamath Lake

Although suckers of all age classes are present in Upper Klamath Lake, population densities of suckers are low, and there are no signs that the populations are returning to their previously high abundance.

Suckers spawn in tributaries to Upper Klamath Lake, but they are blocked from much potentially suitable spawning habitat by Chiloquin Dam on the Sprague River (Figure S-1). Numerous smaller blockages and diversions also are present but are poorly documented. Expansion of spawning on the Sprague River could increase the abundance of fry descending to Upper Klamath Lake and would beneficially extend the interval over which they arrive at the lake.

The water quality of the tributaries to Upper Klamath Lake is poor for some native fishes but is probably adequate for the listed suckers. The tributaries do, however, show loss of riparian vegetation and wetland (largely due to agricultural practices), which could adversely influence the survival of fry. The physical condition of channels in general and spawning areas in particular is degraded, but the nature and extent of degradation is poorly documented for the tributaries.

Endangered suckers also spawn near springs that emerge at the margin of Upper Klamath Lake. Some apparently suitable spawning sites are no longer used, probably because entire groups of fish that used the sites were eliminated during the era of fishing, which ended in 1987. Lakeside spawning behaviors are associated with a specific range of depth. During dry years, the amount of appropriate spawning substrate with appropriate water depth is reduced by drawdown of the lake. Data on year-class strength show no indication of a relationship between year-class strength and water level, which might be expected if drawdown were strongly suppressing production of fry.

Fry are strongly dispersed from their points of origin by currents and ultimately are found in shallow water in or near emergent vegetation at the margins of the lake. Loss of such vegetation, especially near the tributary mouths, could be disadvantageous to the fry. The area around the lake associated with preferred depths and presence of emergent vegetation varies with water level; drawdown, especially in dry years, reduces this area. Standardized sampling of fry and studies of year-class strength for large fish do not, however, indicate associations between water level and abundance of larvae.

Juveniles seek somewhat deeper water than larvae. There is substantial juvenile mortality, but current information is insufficient to show whether it is extraordinary in comparison with mortality in other lakes that have more favorable living conditions.

Subadult and adult fish seek deeper water than younger fish and congregate in specific areas of Upper Klamath Lake. In contrast to the tributaries, poor water quality in the lake itself appears to be their greatest vulnerability. Direct evidence of harm to large fish by poor water quality includes physical indications of stress and mass mortality of large fish ("fish kills") at times of exceptionally poor water quality.

Mass mortality of large fish occurs during the second half of the growing season, but not in all years. Upper Klamath Lake is hypertrophic (extremely productive) because its rich supplies of phosphorus lead to extreme abundance of phytoplankton dominated by *Aphanizomenon flos-aquae*, a nitrogen-fixing bluegreen (cyanobacterial) alga. High abundances of *Aphanizomenon* induce high pH through high rates of photosynthesis. Although strong algal blooms of this type occur each year, conditions for mass mortality are associated with a specific sequence of weather events involving calm weather succeeded by windy weather.

Low concentrations of dissolved oxygen probably are the immediate cause of death of endangered suckers during episodes of mass mortality, but other water-quality factors may contribute to stress. Mass mortality of large fish in Upper Klamath Lake has occurred for many decades, but anthropogenic factors, especially those leading to strong dominance of *Aphanizomenon*, probably have increased its severity and frequency. Poor water quality may also challenge the sucker populations in other ways. High pH, for example, could be harmful to young fish even if they are not subject to the mass mortality of larger fish.

Because hypertrophic conditions indicate very high supplies of phosphorus, much attention has been given to the possibility of reducing the phosphorus load passing from the watershed to Upper Klamath Lake. The prospects for suppressing algal blooms by this means in Upper Klamath Lake seem poor, however, because about 60% of the external phosphorus load is derived from natural sources. In addition, the anthropogenic component of load is accounted for by dispersed sources, which are difficult to control, and the internal load (phosphorus released from lake sediments) is about double the external load.

The key change over the last 50 yr in Upper Klamath Lake probably was the rise of *Aphanizomenon*, which replaced diatoms as the dominant type of algae. Diatoms probably were limited by nitrogen depletion and thus were unable to use fully the rich phosphorus supplies of the lake, whereas *Aphanizomenon* is able to fix nitrogen and thus can fully exploit the high availability of phosphorus, which causes it to reach very high abundances. Various anthropogenic factors could have contributed to the rise of *Aphanizomenon*; one example is increased transparency of the lake caused by disconnection of its associated wetlands, which were sources of dark humic compounds. Reestablishment of these sources would seem advisable but may be impractical because the organic deposits in the wetlands oxidized extensively after the wetlands were drained.

There is no evidence of a causal connection between water level and water quality or fish mortality over the broad operating range in the 1990s, the period for which the most complete data are available for Upper Klamath Lake. Neither mass mortality of fish nor extremes of poor water quality shows any detectable relationship to water level. Thus, despite theoretical speculations, there is no basis in evidence for optimism that manipulation of water levels has the potential to moderate mass mortality of suckers in Upper Klamath Lake. Planning must anticipate that poor water quality will continue to affect the sucker populations of Upper Klamath Lake.

Suckers in Upper Klamath Lake also are affected by entrainment from the Link River near the outflow of the lake. Screens installed at the main irrigation-water withdrawal point probably will be beneficial, but loss of small fish still can be expected. The Link River Dam intakes still are not screened.

Nonnative fishes, which are diverse and abundant in Upper Klamath Lake, may be suppressing the populations of endangered suckers there, but no practical mechanisms for reducing their abundance are known.

### Other Locations in the Klamath Basin

Below Upper Klamath Lake, waters of the upper basin collect through the Lost River system, which is regulated by the Klamath Project (Figure S-1). The headwaters include tributaries to Clear Lake and Gerber Reservoir. These tributaries support recurrently successful spawning of endangered suckers, as shown by the apparently stable populations of suckers in the two reservoirs. Unprecedented drawdown of both reservoirs in the drought year of 1992 coincided with deteriorating body condition and increased incidence of parasitism in the suckers. Thus, the conditions of 1992 have been used by USFWS in setting thresholds of water level for these lakes.

On the Lost River below Gerber Reservoir and Clear Lake (Figure S-1), all waters are strongly affected by the Klamath Project and are unsuitable for suckers, although they still offer some opportunities for restoration, especially through increases in water depth for Tule Lake Sumps and Lower Klamath Lake.

Reservoirs of the mainstem Klamath have created new habitat capable of holding endangered suckers, but recruitment of young fish has not been observed. Reservoirs have low potential to support self-sustaining populations.

## Coho Salmon

The peak migration of adult coho salmon in the Klamath basin occurs between late October and mid-November; the fish spawn primarily in tributaries. Fry reach peak abundance in

March and April, and can disperse as far as the tributary mouths, but most appear to stay close to the areas where they originate. Coho develop through the juvenile stage in the tributaries over about 1 yr. They may occupy the main stem at times but are nearly absent from it by late summer, when the water is warmest. Winter habitat in the tributaries is critical for the juvenile coho but has not been well studied.

Juveniles smoltify and migrate downstream in spring, with a peak in April. Short transit times facilitated by high flow could be favorable to the migrating smolts, although this has not been demonstrated for the Klamath River. Smolts spend approximately 1 mo in the estuary and then enter the ocean, where they spend about 1.5 yr before returning to the Klamath River. Ocean conditions such as productivity affect the strength of year classes.

The most important cause of impairment of coho salmon probably is excessively high summer temperatures in tributary waters. Coho salmon, unlike Chinook salmon, remain in fresh water for an entire year, during which they mainly occupy tributaries, where summer water temperatures can be dangerously high. Causes of extreme temperatures include diversion of cold flows for use in agriculture, flow depletion that leads to warming of cool water, and destruction of riparian vegetation that leads to loss of shading. Temperatures also are excessively high in the main stem, but at present high temperatures there probably are more relevant to other species that are more likely than coho to use the main stem for rearing. Decrease in mainstem temperatures by augmentation of mainstem flows is problematic because augmentation water must be derived from the surface layer of Iron Gate Reservoir, which is very warm in summer. Projections of benefit to be expected from possible thermal manipulations may not have taken into account the exceptional importance of nocturnal thermal minimums in determining the energetic balance of coho exposed to high temperatures; nocturnal minimums can be as important as daily maximums in determining the survival of juvenile coho salmon.

Barriers to passage caused by dams and diversion structures are important to coho salmon. The mainstem dams on the Klamath River block spawning movements, as do Dwinnell Dam on the upper Shasta River and the Trinity River Diversion project on the Trinity River. Numerous small dams used by individual irrigators or ditch companies also block movement of coho in tributaries. Dams also have contributed to habitat degradation.

Coho habitat has been seriously degraded in the tributaries. Lack of cover and impairment of substrate through deposition of sediments are common. Woody debris, which is critical as cover for young fish, has largely been lost as a result of human activity. Excessive depletion of flow may separate fish from adequate habitat in the last half of summer.

Competition between hatchery coho and the smaller wild coho during migration to the estuary may be severe. Probably even more important are competition and predation from large numbers of Chinook salmon and steelhead that are released from hatcheries to the main stem when smoltification of the coho is in progress.

## The Klamath River Fish Kill of 2002

During the second half of September 2002, numerous fish died in the lowermost 40 mi of the Klamath River main stem, 150 mi below Iron Gate Dam (Figure S-1). Most of the dead fish were adult Chinook salmon that had just entered the lower Klamath River. At least 33,000

Chinook, of a total estimated spawning run of about 130,000, died. The immediate cause of death was massive infection by two types of pathogens that are widely distributed and generally become harmful to fish under stress, particularly if crowding occurs. The fish kill, although important for Chinook salmon, did not involve many coho salmon (about 1% of the total dead fish) because coho enter the river later than Chinook, and thus were mostly absent when conditions leading to mass mortality occurred.

The California Department of Fish and Game (CDFG), through an analysis of environmental conditions over 5 yr of low flow within the last 15 yr, showed that neither the flows nor the temperatures that occurred in the second half of September 2002 were unprecedented. A study by the U.S. Geological Survey (USGS) supports this conclusion. Thus, no obvious explanation of the fish kill based on unique flow or temperature conditions is possible.

CDFG has proposed that the shape of the channel in the lowermost reaches of the Klamath main stem changed in 1997-1998 under the influence of high flows, which caused fish entering the river to be unable to proceed upstream under low-flow conditions. An alternate hypothesis is that an unusual combination of temperature, flow, and migration conditions occurred in 2002, possibly in association with weather that prevented the river from showing nocturnal cooling to an extent that would usually be expected.

The two hypotheses—or others that may be proposed—are difficult to test because the conditions coinciding with the fish kill were unexpected and therefore largely unmonitored. If a lasting change in channel configuration was responsible, recurrence of the episode can be expected with similar low flows in the future. If other factors were responsible, recurrence may be much less likely. It is unclear what the effect of specific amounts of additional flow drawn from controllable upstream sources (waters from reservoirs on the Trinity River or Iron Gate Reservoir) would have been. Flows from the Trinity River could be most effective in lowering temperature.

## Legal, Regulatory, and Administrative Context of Recovery Actions

Adaptive management is accepted in principle by the listing agencies but has not been implemented in the Klamath basin for the benefit of the listed species, except as part of the Trinity River Restoration Project. Information collected through monitoring and research has been valuable, but the absence of an integrated, evolving management plan connected to monitoring, research, review, and periodic readjustment of management actions will hamper progress in the future. Although agencies must meet the requirements of the ESA, many actions that could benefit the listed species can also be justified from the viewpoint of ecosystem management favorable to numerous other species, some of which are perilously close to listing, and to ecosystem functions that have great practical value.

Specifically with reference to ESA Section 4(f), USFWS and NMFS recovery planning for the three listed species has stalled and needs to be revived. Jeopardy consultations, which have focused on operation of the Klamath Project, must be broadened geographically because critical environmental resources of the listed species are found not only in but also beyond the Klamath Project. Furthermore, USFWS and NMFS appear to have overlooked take (mortality and impairment) of the listed species that is incidental to agricultural practice, private water management, and other activities beyond the control of USBR, and thus have not taken full advantage of their authorities under ESA Section 9.

The listing agencies have been criticized for using pseudoscientific reasoning ("junk science") in justifying their requirements for the protection of species in the upper Klamath basin. The committee disagrees with this criticism. The ESA allows the agencies to use a wide array of information sources in protecting listed species. The agencies can be expected, when information is scarce, to extend their recommendations beyond rigorously tested hypotheses and into professional judgment as a means of minimizing risk to the species. In allowing professional judgment to override site-specific evidence in some cases during 2001, however, the agencies accepted a high risk of error in proposing actions that the available evidence indicated to be of doubtful utility. The committee, as explained in its interim report, found some proposed actions as given in the 2001 biological opinions to lack substantial scientific support. In their biological opinions of 2002, the listing agencies appear to have resolved this issue either by obtaining concessions from USBR through mechanisms that are generally consistent with USBR's goal of delivering irrigation water (for example, through establishment of a water bank) or by redesigning their requirements to bring them into greater conformity with the existing evidence.

## RECOMMENDATIONS

Recovery of endangered suckers and threatened coho salmon in the Klamath basin cannot be achieved by actions that are exclusively or primarily focused on operation of USBR's Klamath Project. While continuing consultation between the listing agencies and USBR is important, distribution of the listed species well beyond the boundaries of the Klamath Project and the impairment of these species through land- and water-management practices that are not under control of USBR require that the agencies use their authority under the ESA much more broadly than they have in the past.

Recommendation 1. The scope of ESA actions by NMFS and USFWS should be expanded in several ways, as follows (Chapters 6, 8, 9).

- NMFS and USFWS should inventory all governmental, tribal, and private actions that are causing unauthorized take of endangered suckers and threatened coho salmon in the Klamath basin and seek either to authorize this take with appropriate mitigative measures or to eliminate it.
- NMFS and USFWS should consult not only with USBR, but also with other federal agencies (e.g., U.S. Forest Service) under Section 7(a)(1); the federal agencies collectively should show a will to fulfill the interagency agreements that were made in 1994.
- NMFS and USFWS should use their full authority to control the actions of federal agencies that impair habitat on federally managed lands, not only within but also beyond the Klamath Project.
- Within 2 yr, NMFS should prepare and promulgate a recovery plan for coho salmon, and USFWS should revise the recovery plan for shortnose and Lost River suckers. The new recovery

plans should facilitate consultations under ESA Sections 7(a)(1), 7(a)(2), and 10(a)(1) across the entire geographic ranges of the listed species.

- NMFS and USFWS should more aggressively pursue opportunities for non-regulatory stimulation of recovery actions through the creation of demonstration projects, technical guidance, and extension activities that are intended to encourage and maximize the effectiveness of non-governmental recovery efforts.

Recommendation 2. Planning and organization of research and monitoring for listed species should be implemented as follows (Chapters 6, 8, 10).

- Research and monitoring programs for endangered suckers should be guided by a master plan for collection of information in direct support of the recovery plan; the same should be true of coho salmon.
- A recovery team for suckers and a second recovery team for coho salmon should administer research and monitoring on the listed species. The recovery team should use an adaptive management framework that serves as a direct link between research and remediation by testing the effectiveness and feasibility of specific remediation strategies.
- Research and monitoring should be reviewed comprehensively by an external panel of experts every 3 yr.
- Scientists participating in research should be required to publish key findings in peer-reviewed journals or in synthesis volumes subjected to external review; administrators should allow researchers sufficient time to do this important aspect of their work.
- Separately or jointly for the upper and lower basins, a broadly based, diverse committee of cooperators should be established for the purpose of pursuing ecosystem-based environmental improvements throughout the basin for the benefit of all fish species as a means of preventing future listings while also preserving economically beneficial uses of water that are compatible with high environmental quality. Where possible, existing federal and state legislation should be used as a framework for organization of this effort.

Recommendation 3. Research and monitoring on the endangered suckers should be continued. Topics for research should be adjusted annually to reflect recent findings and to address questions for which lack of knowledge is a handicap to the development or implementation of the recovery plan. Gaps in knowledge that require research in the near future are as follows (Chapters 5, 6).

- Efforts should be expanded to estimate annually the abundance or relative abundance of all life stages of the two endangered sucker species in Upper Klamath Lake.
- At intervals of 3 yr, biotic as well as physical and chemical surveys should be conducted throughout the geographic range of the endangered suckers. Suckers should be sampled for indications of age distribution, qualitative measures of abundance, and condition factors. Sampling should include fish other than suckers on grounds that the presence of other fish is an indicator of the spread of nonnative species, of changing environmental conditions, or of changes in abundance of other endemic species that may be approaching the status at which listing is needed. Habitat conditions and water-quality information potentially relevant to the welfare of the suckers should be recorded in a manner that allows comparison across years. The resulting

survey information, along with the more detailed information available from annual monitoring of populations in Upper Klamath Lake, should be synthesized as an overview of status.

- Detailed comparisons of the Upper Klamath Lake populations (which are suppressed) and the Clear Lake and Gerber Reservoir populations (which are apparently stable), in combination with studies of the environmental factors that may affect welfare of the fish, should be conducted as a means of diagnosing specific life-history bottlenecks that are affecting the Upper Klamath Lake populations.
- Multifactorial studies under conditions as realistic as practicable should be made of tolerance and stress for the listed suckers relevant to poor water-quality conditions in Upper Klamath Lake and elsewhere.
- Factors affecting spawning success and larval survival in the Williamson River system should be studied more intensively in support of recovery efforts that are focused on improvements in physical habitat protection for spawners and larvae in rivers.
- An analysis should be conducted of the hydraulic transport of larvae in Upper Klamath Lake.
- Relevant to the water quality of Upper Klamath Lake, more intensive studies should be made of water-column stability and mixing, especially in relation to physiological status of *Aphanizomenon* and the occurrence of mass mortality; of mechanisms for internal loading of phosphorus; of winter oxygen concentrations; and of the effects of limnohumic acids on *Aphanizomenon.*
- A demographic model of the populations in Upper Klamath Lake should be prepared and used in integrating information on factors that affect individual life-history stages.
- Studies should be done on the degree and importance of predation on young fish by nonnative species.
- Additional studies should be done on the genetic identities of subpopulations.

<u>Recommendation 4</u>. Recovery actions of highest priority based on current knowledge of endangered suckers are as follows (Chapter 6):

- Removal of Chiloquin Dam to increase the extent of spawning habitat in the upper Sprague River and expand the duration over which larvae enter Upper Klamath Lake.
- Removal or facilitation of passage at all small blockages, dams, diversions, and tributaries where suckers are or could be present.
- Screening of water intakes at Link River Dam.
- Modification of screening and intake procedures at the A Canal as recommended by USFWS (2002).
- Protection of known spawning areas within Upper Klamath Lake from disturbance (including hydrologic manipulation, in the case of springs), except for restoration activities.
- For river spawning suckers of Upper Klamath Lake, protection and restoration of riparian conditions, channel geomorphology, and sediment transport; elimination of disturbance at locations where suckers do spawn or could spawn. These actions will require changes in grazing and agricultural practices, land management, riparian corridors, and public education.
- Seeding of abandoned spawning areas in Upper Klamath Lake with new spawners and physical improvement of selected spawning areas.

- Restoration of wetland vegetation in the Williamson River estuary and northern portions of Upper Klamath Lake.
- Use of oxygenation on a trial basis to provide refugia for large suckers in Upper Klamath Lake.
- Rigorous protection of tributary spawning areas on Clear Lake and Gerber Reservoir, where populations are apparently stable.
- Reintroduction of endangered suckers to Lake of the Woods after elimination of its nonnative fish populations.
- Reestablishment of spawning and recruitment capability for endangered suckers in Tule Lake and Lower Klamath Lake, even if the attempts require alterations in water management, provided that preliminary studies indicate feasibility; increased control of sedimentation in Tule Lake.
- Review of all proposed changes in Klamath Project operations for potential adverse effects on suckers; maintenance of water level limits for the near future as proposed by USBR in 2002 but with modifications as required by USFWS in its most recent biological opinion (2002).

Recommendation 5. Needs for new information on coho salmon are as follows (Chapters 7, 8).

- Annual monitoring of adults and juveniles should be conducted at the mouths of major tributaries and the main stem as a means of establishing a record of year-class strength for coho. Every 3 yr, synoptic studies of the presence and status of coho should be made of coho in the Klamath basin. Physical and chemical conditions should be documented in a manner that allows interannual comparisons. Not only coho but other fish species present in coho habitats should be sampled simultaneously on grounds that changes in the relative abundance of species are relevant to the welfare of coho and may serve as an early warning of declines in the abundance of other species. Results of synoptic studies, along with the annual monitoring at tributary mouths, should be synthesized as an overview of population status at 3-yr intervals.
- Detailed comparisons should be made of the success of coho in specific small tributaries that are chosen so as to represent gradients in potential stressors. The objective of the study should be to identify thresholds for specific stressors or combinations of stressors and thus to establish more specifically the tolerance thresholds for coho salmon in the Klamath basin.
- The effect on wild coho of fish released in quantity from hatcheries should be determined by manipulation of hatchery operations according to adaptive-management principles. As an initial step, release of hatching fish from Iron Gate Hatchery (all species) should be eliminated for 3 yr, and indicators of coho response should be devised. Complementary manipulations at the Trinity River Hatchery would be desirable as well.
- Selected small tributaries that have been impaired should be experimentally restored, and the success of various restoration strategies should be determined.
- Success of specific livestock-management practices in improving channel conditions and promoting development of riparian vegetation should be evaluated systematically.
- Relationships between flow and temperature at the junctions of tributaries with the main stem and the estuary should be quantified; possible benefits of coordinating flow management in the Trinity and Klamath main stem should be studied.

Recommendation 6. Remediation measures that can be justified from current knowledge include the following (Chapter 8).

- Reestablishment of cool summer flows in the Shasta and Scott rivers in particular but also in small tributaries that reach the Klamath main stem or the Trinity main stem where water has been anthropogenically warmed. Reestablishment of cool flows should be pursued through purchase, trading, or leasing of groundwater flows (including springs) for direct delivery to streams; by extensive restoration of woody riparian vegetation capable of providing shade; and by increase of summer low flows.
- Removal or provision for effective passage at all small dams and diversions throughout the distribution of the coho salmon, to be completed within 3 yr. In addition, serious evaluation should be made of the benefits to coho salmon from elimination of Dwinnell Dam and Iron Gate Dam on grounds that these structures block substantial amounts of coho habitat and, in the case of Dwinnell Dam, degrade downstream habitat as well.
- Prescription of land-use practices for timber management, road construction, and grazing that are sufficiently stringent to prevent physical degradation of tributary habitat for coho, especially in the Scott, Salmon, and Trinity river basins as well as small tributaries affected by erosion.
- Facilitation through cooperative efforts or, if necessary, use of ESA authority to reduce impairment of spawning gravels and other critical habitat features by livestock, fine sediments derived from agricultural practice, timber management, or other human activities.
- Changes in hatchery operations to the extent necessary, including possible closure of hatcheries, for the benefit of coho salmon as determined through research by way of adaptive management of the hatcheries.

## COSTS

The costs of remediation actions are difficult to estimate without more detail on their mode of implementation by the agencies. Based on general knowledge of costs of research and monitoring at other locations, an approximate figure for the recommendations on endangered suckers over a 5-yr period is approximately $15-20 million, including research, monitoring, and remedial actions of minor scope. Excluded are administrative costs and the costs of remedial actions of major scope (e.g., removal of Chiloquin Dam), which would need to be evaluated individually for cost. For coho salmon, research, monitoring, and remedial projects of small scope over 5 yr is estimated at $10-15 million. Thus, the total for all three species over 5 yr is $25-35 million, excluding major projects such as removal of dams. These costs are high relative to past expenditures on research and remediation in the basin, but the costs of further deterioration of sucker and coho populations, along with crisis management and disruptions of human activities, may be far more costly. A hopeful vision is that increased knowledge, improved management, and cohesive community action will promote recovery of the fishes. This outcome, which would be of great benefit to the Klamath basin, could provide a model for the nation.